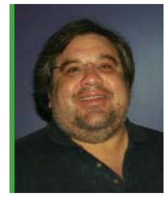
High-Stiffness Hybrid Passive/Active Magnetic Bearing for Precision Engineering Applications



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We intend to develop a dynamically stable, high-stiffness, hybrid passive/active magnetic bearing for the ultra-precise machining of parts. This bearing is to have low error motion so that it will be able to perform in this highly stringent application. Low error motion is defined to be 50 nm or less in this case. This study will show that, theoretically, the rotor error motions due to mass imbalance and internal/external excitation sources can be rendered negligible.

Additionally, we develop a methodology to initially align the rotor to meet our "error budget." At the same time, we must develop an active control scheme to take care of the residual rotor error motion.

Project Goals

The end result of this project will be the demonstration of the feasibility of our bearing concept. Also, we plan to have an initial design for a prototype of a hybrid passive/active magnetic bearing with the stiffness and stability for precision machining operations that will meet or exceed state-of-the-art tolerance limits.

Relevance to LLNL Mission

Applications of improved precision machining include mirrors for laser-optic systems, telescope mirrors for basic science and reconnaissance, and high-energy-density physics targets, all pertaining to key LLNL missions in national security. In particular, the goal of achieving inertial confinement fusion using lasers is dependent on the precision of the system's optical components.

FY2004 Accomplishments and Results

This study has shown, theoretically, that rotor error motions due to mass imbalance and internal/external excitation sources can be rendered negligible.

We also met our goal of developing a methodology to initially align the rotor to meet our error budget constraint. At the

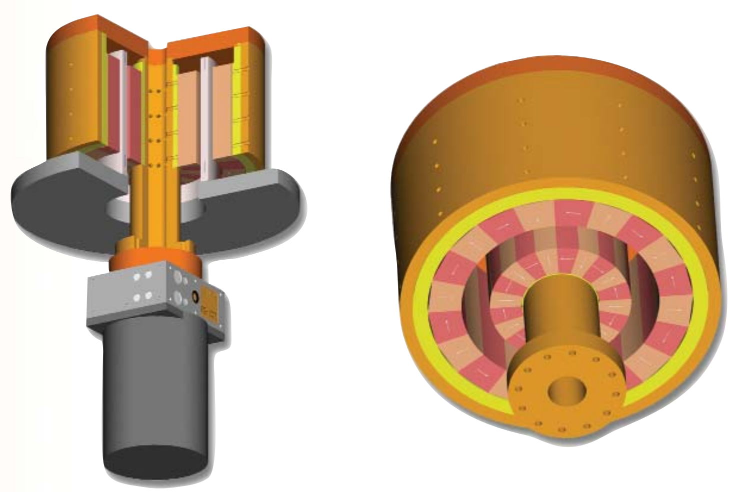

Figure 1. Views of the preliminary design of prototype hybrid passive/active magnetic bearing.

same time, we developed an active control scheme to take care of the residual rotor error motion. Our results indicate that it is possible to meet all error budget and design constraints. We conclude that it is quite feasible that the proposed bearing can be constructed and meet all design criteria. This has led to the preliminary design of a prototype machine using a hybrid magnetic bearing (see Fig. 1).

This prototype, because of the versatility of the Halbach design, is able to operate stably over a large range of spindle RPM (Ω) and spindle overhang (l_H). Stability is ensured whenever Re (λ) <0 (see Fig. 2).

Figure 3 is the Campbell diagram of the system. The red lines are sources of rotor excitation and the blue lines are whirl modes as a function of rotor RPM. At the RPM (Ω) where these lines cross, there is potential for large amplitude vibration. The Halbach array can easily be designed such that the system operates at a point where it is insensitive to these excitations.

In summary, this hybrid bearing will be capable of stable dynamic operation and high stiffness over a large range of rotor RPM. "Designing-in" insensitivity to internal or external excitation at operating speed allows for a low error-motion capability in the passive component. The active control system will then eliminate any residual error motion.

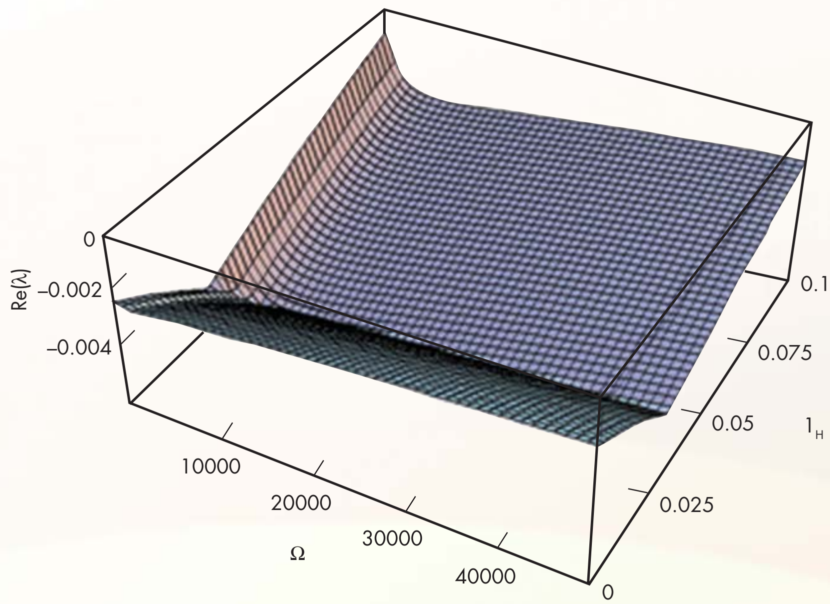

Figure 2. Rotor-dynamic stability diagram.

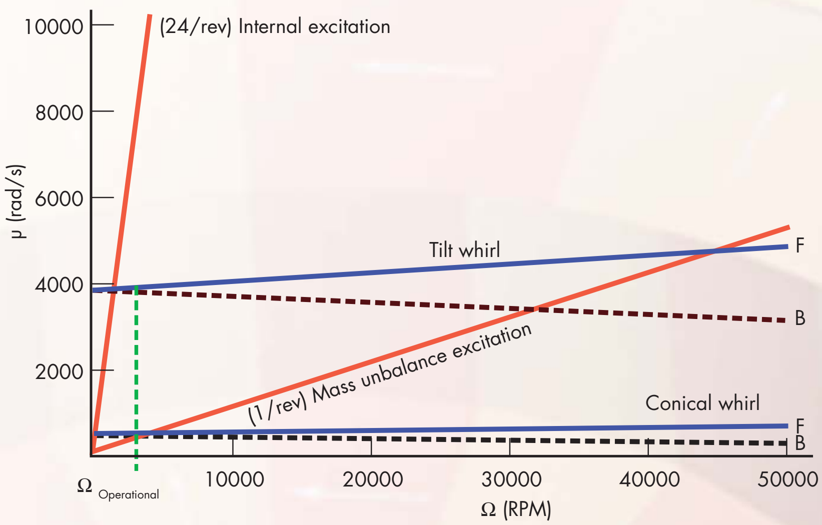

Figure 3. Campbell diagram.